ANALYSES OF THREE CLASSES OF SMALL LUNAR PYROCLASTIC DEPOSITS WITH CLEMENTINE DATA.
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INTRODUCTION: We used the USGS ISIS software ([1],[2],[3]) to create and examine Clementine UVVIS multispectral mosaics (~100 m/pixel) of areas representative of the three major compositional classes of small lunar pyroclastic deposits (e.g., [4]). Compositional analyses of these deposits may provide clues to the nature of deep-source, late-stage volcanism and eruption mechanisms on the Moon. We are studying small deposits of the Atlas Crater, east of Aristoteles, and J. Herschel Crater regions. Our goals are (1) to understand the full extent of interdeposit compositional variations among small lunar pyroclastic deposits; (2) to evaluate the possible effects of soil maturation and lateral mixing on the "true" compositions of these deposits; (3) to determine the prevalence and nature of intradeposit compositional variations previously observed in deposits of Alphonsus Crater [5]; (4) to identify and characterize the juvenile components of these deposits; and (5) to understand the implications of these results for studying lunar eruption mechanisms.

DATA PROCESSING: The Clementine data were obtained by the UVVIS camera at 5 wavelengths: 415, 750, 900, 950, and 1000 nm. ISIS processing of the raw Clementine data included: offset and gain corrections, dark-current subtraction, readout correction, flat-field corrections, subpixel-level coregistration, projection to Sinusoidal Equal-Area, photometric normalization (to standard viewing angles of phase=30 degrees, e=0 degrees, and i=30 degrees) and automated mosaicking. The data were calibrated to reflectance (I/F) to facilitate compositional analyses [6]; calibration will be updated as flat-field, photometric, and other calibration files are refined.

PREVIOUS WORK: More than 75 lunar pyroclastic deposits have been recognized (e.g., [4],[7],[8]). They are commonly dark and smooth-surfaced, and they are observed in association with sinuous rilles, irregular depressions, or endogenic craters within highlands and/or the floors of old impact craters situated along the margins of many of the major mare-filled impact basins on the lunar near side. A small number of pyroclastic deposits have been found on the lunar far side; examples are found in the floor of Schrodinger Crater [9] and in the Apollo Basin within the far side South Pole/Aitken Basin [10]. Lunar pyroclastic deposits have been subdivided into "regional" and "localized" deposits on the basis of size, morphology, and occurrence; regional deposits can be up to several 1000 km^2 in size, while localized or small pyroclastic deposits are typically only 200 to 500 km^2 in size [7]. Regional deposits are thought to have been emplaced as products of continuous or Strombolian-style eruptions, with wide dispersion of well-sorted pyroclasts [11]. Analyses of Apollo samples and Earth-based spectral reflectance studies have identified a significant component of Fe2+-bearing volcanic glass beads in many of the regional pyroclastic deposits (e.g., [7],[12]).

Intermittent or Vulcanian-style eruptions are likely to have produced the small pyroclastic deposits, with explosive decompression acting to remove a plug of lava within a conduit and to form an endogenic vent crater [13]. The small pyroclastic deposits have been further subdivided into three compositional classes on the basis of their "1.0-micron" or mafic absorption bands in Earth-based spectra (e.g., [4]). Mafic bands of small pyroclastic deposits in the Group 1 class are centered near 0.93 to 0.95 microns, have depths of 4 to 5%, and are asymmetrical, with "checkmark"-like shapes (straight, steep, short-wavelength edges and shallow, straight, long-wavelength edges). Spectra for Group 1 deposits resemble those of typical highlands and are indicative of the presence of feldspar-bearing mafic assemblages which are dominated by orthopyroxene. Although compositional variation is observed within different Group 1 deposits, most appear to be mixtures of highlands-rich country rock and glass-rich juvenile material with small amounts of basaltic caprock material. Examples of Group 1 small pyroclastic deposits are found on the floors of Atlas Crater (45°N, 45°E), Franklin Crater (29°N, 48°E), and near Grimaldi Crater (1°S, 64°W). Mafic bands in spectra for Group 2 deposits are centered near 0.96 microns, have depths of ~7%, and are symmetrical in shape. Group 2 spectra are similar to those of mature mare deposits, and they are dominated by clinopyroxene. Small pyroclastic deposits in Group 2 appear to consist largely of fragmented plug rock material, with insignificant amounts of highland and juvenile materials. Examples of Group 2 deposits are the two small deposits east of Aristoteles Crater (50°N, 21°E and 28°E), and Rima Fresnel pyroclastics (28°N, 4°E). Group 3 mafic bands are centered near 1.0 micron, have depths of ~5 to 7%, are relatively broad and asymmetrical, and are probably multiple bands. Spectra of Group 3 deposits are dominated by olivine and orthopyroxene; the olivine is almost certainly associated with juvenile material, and the orthopyroxene is likely to have been emplaced as a result of erosion and entrainment of the wall rock [6]. Examples of Group 3 small pyroclastic deposits are those of J. Herschel Crater (62°N, 42°W), Alphonsus Crater (13°S, 4°W), and south of Cruger Crater (17.5°S, 67°W).

RESULTS AND DISCUSSION: To examine the compositional relations among the three classes of small lunar pyroclastic deposits, we compared ratios of reflectance values for the deposits at Atlas Crater (Group 1), east of Aristoteles West (Group 2), and J. Herschel Crater (Group 3). The ratios examined are the 450nm/750nm or uv/vis ratio, suggestive of relative titanium content (high="blue";

low="red"; e.g., [14]), and the 950nm/750nm ratio, a measure of the 1.0-micron band strength and suggestive of relative mafic content (low=strong or deep 1.0-micron band; high=weak or shallow band). These ratio values can also be interpreted in terms of relative soil maturity: a mature soil is red and has a relatively shallow 1.0-micron band, while a more immature soil is blue, with a deeper 1.0-micron band [e.g., 15]. Figure 1 shows ratio values extracted from each of the 3 classes, with samples obtained from near the probable vent areas (usually an irregular depression) and trending outward (but not into the diffuse zone at the margins of the deposits). The scatter in the Group 1/Atlas deposits is likely to be due to their very small size (~20 km dia.) and the fact that two separate vents are measured (the southern vent is marked in Figure 1; the northern vent is lower in the figure, between the Group 1 and 2 vent sites). Although there is some overlap in the 950/750 nm ratio values, each of the three compositional groups can be distinguished. In general, the 1.0-micron band depth increases from Group 1 values to Group 3 values. These results confirm previous work [e.g., 4] and suggest that primary compositional differences (rather than age) account for the observed spectral variation between small pyroclastic deposits. Intradeposit compositional variation is also observed: in these examples, the 1.0-micron band depth becomes slightly deeper as distance from the vent increases. This relationship is in contradiction to that previously observed for Alphonsus Crater deposits [5] in which the more mature "dark-interior" units were redder and had shallower mafic bands than outer portions of the deposits. This apparent contradiction further suggests that soil maturation (age) effects are not dominant in the spectra for small pyroclastic deposits presented here. One possibility is that our observed trends (shallower bands and redder soils near the vents) may represent primary compositional aspects of the small pyroclastic deposits; the latter stages of eruption may be dominated by nonjuvenile wall and cap rock materials. In this case, the medial portions of the small pyroclastic deposits may reveal their "true" or primary compositions. We are continuing to investigate these and other possibilities in our detailed analyses of the Clementine UVVIS data of small lunar pyroclastic deposits.

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FIGURE 1: Clementine UVVIS data: Comparisons of color ratio data for three types of small pyroclastic deposits on the Moon.